Diagnostic Value of MRI CSF Flowmetry for the Diagnosis of Normal Pressure Hydrocephalus

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ABSTRACT

Background: Normal pressure hydrocephalus is a rare disease, with unpredictable surgical outcome after shunt placement. To date, no single diagnostic tool or combination of tools has proved capable of reliably predicting whether the condition of a patient with suspected NPH will improve or not after a shunting procedure. Objective: To evaluate the value of MRI CSF Flowmetry as a non-invasive method to help establish the diagnosis of Normal Pressure Hydrocephalus. Method: Between June 2009 and December 2011, 8 patients in whom NPH had been diagnosed (on the basis of clinical findings and imaging) underwent CSF Flowmetry, and diagnostic lumbar tap for confirmation of diagnosis followed by a programmable shunt insertion. A review and analysis of the surgical outcome of the 8 cases was done. Result: Variable degrees of improvement were noted in all patients. 75% of cases had gait and cognitive improvement. 50 % of cases had improved bladder control. It was noted that the degree of improvement was better in patients with higher preoperative stroke volume. Conclusion: MRI CSF Flowmetry proved to be a reliable, safe and non invasive investigation to be used for the diagnosis of normal pressure hydrocephalus - To start reconsidering the need for the diagnostic lumbar tap; further studies are needed, with more patients and longer follow up periods. [Egypt J Neurol Psychiat Neurosurg. 2012; 49(3): 277-282]

Key Words: Normal pressure hydrocephalus, Shunt placement, Cerebrospinal fluid hydrodynamics, Programmable shunt

INTRODUCTION

In 1965, Hakim and Adams proposed for the first time a form of communicating hydrocephalus that could result in a treatable dementia. The CSF pressure in those patients is generally normal1. The diagnosis and management of idiopathic normal-pressure hydrocephalus (INPH) remains unclear. Many supplementary tests have been used to predict which patients would benefit from placement of a shunt, but the value of those tests have not been established5. To distinguish which older patients with ventriculomegaly and suspected normal pressure hydrocephalus (NPH) should undergo surgical shunting remains difficult as the differential diagnosis of the disease includes all types of dementia, and traumatic and vascular brain atrophy5.

MRI is very sensitive to fluid motion. This normal movement of CSF results in a loss of signal (flow void) within the cerebral aqueduct. In NPH, CSF flow is hyperdynamic, with an increase in the amount and velocity of CSF passing rostrally, then caudally, through the cerebral aqueduct with each cardiac cycle. This was characterized by enlargement of the CSF flow void within the cerebral aqueduct and the fourth ventricle on axial T2-weighted magnetic resonance imaging (MRI) scans. This new MRI technique allows quantification of CSF flow. Measurements are performed in the cerebral aqueduct, the narrowest portion of the ventricular system and therefore the location of highest CSF flow velocity.

Since CSF motion is pulsatile, the average of the volume of CSF moving caudally during systole and rostrally during diastole is calculated. This is defined as the CSF stroke volume. It was found in the initial study with this technique that CSF stroke volumes above 42 microliter were associated with a favorable response to shunting. This is a promising tool for screening patients with clinical symptoms of NPH and thus identifying a treatable dementia without risking postsurgical complications in patients who will not benefit.

PATIENTS AND METHODS

Between June 2009 and December 2011, 12 patients presented with clinical syndrome suggestive of NPH (Dementia, gait disturbance). They were subjected to the following:

Evaluation:
I. Clinical assessment:
Full Medical History and Clinical examination, establishing the diagnosis, Cognitive functions are assessed with the MiniMental State Examination (MMSE)5.

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II. Radiological Assessment:
CT and MRI Brain done demonstrating Ventriclemegaly and any associated pathology. MRI Flowmetry is done in positive cases after clinical improvement following diagnostic lumbar tap, according to the following protocol:

CSF Flowmetry Technique:
Patients underwent the CSF flowmetry examination on MR machine a 1.5-T Super conducting system. The demonstrated technique was applied to all the patients included in this the study; figures below are those of one of the patients included in the study.

CSF flow properties were analyzed at the level of the aqueduct of Sylvius in all patients. A circular polarized head-array coil and ultra gradients and the same parameters of examination were chosen. Conventional MRI of the brain was performed in axial T1WI, axial and sagittal T2WI were obtained (Figure 1).

For phase-contrast MR imaging, the axial technique: CSF flow dynamics were quantitatively studied by using a cardiac gated (ECG being used for cardiac synchronization) high resolution axial phase contrast protocol with an imaging plane perpendicular to the proximal 1/3 of the cerebral aqueduct. The direction of flow encoding was caudo-cranial.

The images were displayed on a gray scale, so as low signal intensity indicated caudal flow while bright signal intensity represented cranial flow.

CSF flow quantification was performed on those phase images using the region-of-interest (ROI) measurements and a CSF flow wave form was generated (Figure 2).

The generated CSF flow wave form analysis:
Plotting time of the cardiac cycle on the x axis and the velocity on the y axis. During CSF diastole, CSF moves in caudo-cranial direction (negative velocity), and during CSF systole, CSF flows in the craniocaudal direction (positive velocity). A corresponding table that shows the CSF velocity and flow values for each time frame is obtained (Figure 3).

Post processing calculations:
Following the acquisition of the CSF flow velocity curves analysis:

The end diastolic peak velocity (in cm/sec), the peak systolic velocity (in cm/sec), mean systolic velocity and flow (in ml/sec). The mean flow was calculated from the following equation: mean flow (in cm³/sec) = mean velocity (in cm/sec) × area of ROI (in cm²), (the mean velocity was automatically determined from the mean value of the obtained velocities of each cardiac phase and the area of ROI detected by the MR unit). Then detection of onset of CSF systole (in msec), time of CSF peak systole (in msec), and duration of CSF systole (in msec).

Calculation of the systolic stroke volume as follows: systolic stroke volume (in microliters) = mean systolic flow × duration of CSF systole.

III. Lumbar Tap:
Lumbar tap was done in left lateral position and CSF manometry and release of 40-50 cm. of CSF was performed and clinical improvement was observed within 72 hours.

Surgical intervention
In Patients with clinical improvement following the lumbar tap (n=8) the following was performed:

a. Operative Intervention: Surgical placement of a programmable ventriculo-peritoneal shunt


Patient who did not improve in cerebrospinal lumbar tap were excluded from this study (n=4).
RESULTS

This study included a total of 8 patients with ventriculomegaly on CT and or conventional MRI with provisional clinical diagnosis of normal pressure hydrocephalus. The diagnosis was confirmed in patients improving clinically after lumbar cerebrospinal tap and with a positive MRI CSF flowmetry and they were operated upon by insertion of a programmable VP shunt. The other 4 patients who did not show clinical improvement after Lumbar tap were excluded from the study.

Age of the patients ranged between 64 and 76 years (mean 68 Years). 63% of patients were males (5/8 cases) and 37% females (3/5 cases). All the patients included suffered the clinical triad of NPH with variable degree of intensity.

CSF flowmetry stroke volume recording showed all 8 patients had a systolic stroke volume above 42 microliters. Range 43-90 microliters. Mean systolic stroke volume 60 microliters.

Clinical outcome: All patients included in this study had clinical improvement in at least one of their symptoms. Gait improvement was found in 75% of cases. Cognitive function also improved in 75% of cases. Bladder control improved in 50% of cases. It was noted that the degree of improvement was better in patients with higher preoperative stroke volume.

Complications: Two cases suffered postoperative subdural hygroma and one case had a thin film of subdural hematoma, the post-operative collections were mild enough not to cause any symptoms, yet they were closely observed. This was managed by elevating the opening pressure of the programmable shunt 2 cm (from 14cm used in all patients to 16 cm) and the collections disappeared on follow up scans and the patients improved.

Follow up period: of patients ranged between 6-24 months. Mean follow up period was 12 months.
### Table 1. NPH patient population and postoperative clinical outcome.

<table>
<thead>
<tr>
<th>Patient</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age/Sex</td>
<td>64/F</td>
<td>68/M</td>
<td>73/M</td>
<td>61/F</td>
<td>76/M</td>
<td>73/M</td>
<td>64/M</td>
<td>66/M</td>
</tr>
<tr>
<td>Stroke Volume*</td>
<td>56</td>
<td>45</td>
<td>90</td>
<td>43</td>
<td>61</td>
<td>86</td>
<td>54</td>
<td>47</td>
</tr>
<tr>
<td>Cognitive Improvement</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Gait Improvement</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>-</td>
</tr>
<tr>
<td>Bladder Improvement</td>
<td>-</td>
<td>-</td>
<td>+</td>
<td>+</td>
<td>+</td>
<td>-</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Operative Complication</td>
<td>Thin Subdural Hygroma</td>
<td>-</td>
<td>Thin Subdural blood</td>
<td>-</td>
<td>Thin Subdural Hygroma</td>
<td>-</td>
<td>Thin Subdural Hygroma</td>
<td>-</td>
</tr>
<tr>
<td>Follow Up / months</td>
<td>10</td>
<td>15</td>
<td>6</td>
<td>8</td>
<td>24</td>
<td>10</td>
<td>6</td>
<td>16</td>
</tr>
</tbody>
</table>

*CSF Flowmetry Systolic Stroke Volume (Microliters)

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**DISCUSSION**

Normal pressure hydrocephalus (NPH) is one of the few causes of dementia that is potentially reversible. The Presentation of NPH can occur in various forms and degrees of each element of the classic triad: dementia, gait disturbance and urinary incontinence. Generally, gait disturbance plus one additional feature is required to consider the diagnosis. Two, forms of NPH exist, idiopathic and secondary. Cases where earlier trauma, hemorrhage, infection, mass lesions, or aqueductal stenosis contribute to hydrocephalus are considered symptomatic or secondary forms of NPH.

In our study, both idiopathic and secondary forms of NPH were included; one case had a history of tumor resection. Two cases had history of cerebrovascular strokes, yet the diagnosis was still established according to criteria mentioned in our study, and clinical improvement was noted in those cases, compared to the other patients in the study who presented with idiopathic type.

Surgical complications in our study was found in 3 patients of postoperative subdural Hygroma and blood collections (38%) of cases, comparable with complication rate of Eide et al., who had a 30% postoperative shunt complication rate in a much larger population of patients. Our complications however were transient and disappeared on follow up, due to raising the opening pressure of the programmable shunts inserted.

Many earlier studies focused on the value of basic tests such as the continuous lumbar drain for diagnosis of NPH, however, Marmarou et al. claimed a positive predictive value of 90.5% in NPH patients who had a clinical improvement after inserting the external lumbar drain, but in his series of 151 patients, 22.3% of patients whose condition was not improved after external lumbar drain had a good outcome after a CSF shunting procedure. Also, such a maneuver is invasive with recorded complications such as wound infection and meningitis and root irritation. Other investigations that were assessed included CSF cisternography and CSF outflow resistance (RO), and lumbar infusion tests, but such invasive tests inspite of their usefulness, showed complications such as headache and signs of meningism thus the interest in their use was fading away.

In the literature, the predictive Value of Aqueductal CSF Flow Velocity was controversial, partially because of the few number of cases and the few number of studies. Bradley et al. After studying 18 patients with suspected NPH, found no statistical significance between aqueductal flow void score and responsiveness to shunting. He noticed on the other hand that a relationship between CSF stroke volume greater than 42 and response to shunting were statistically significant. He also noted no complications related to MRI have been reported.

Marmarou et al. found that, neither MRI CSF flow void sign nor quantitative CSF flow velocity seems to have significant diagnostic value. On the other hand, they also agreed that CSF stroke volume may potentially have greater diagnostic value than aqueductal flow void.

In our study there was an evident correlation between the systolic stroke volume and degree of clinical improvement: all symptoms (dementia, gait and bladder disturbance improved in the patients with systolic stroke volumes above 60 microliters. Kahlon
et al.\textsuperscript{14} and Tarnaris et al.\textsuperscript{15} share our belief that systolic stroke volume is a promising tool in selecting patients with normal pressure hydrocephalus symptoms to shunt surgery.

**Conclusion**

- MRI CSF Flowmetry proved to be a reliable, safe and non-invasive tool of investigation to be used for the diagnosis of normal pressure hydrocephalus.
- To start reconsidering the need for the lumbar tap, further studies are needed, with more patients and longer follow-up periods.
- Programmable shunt, though relatively expensive yet it provided a solution that spared the patients with post-operative subdural collections, the need for another surgery.

[Disclosure: Authors report no conflict of interest]

**REFERENCES**

المنشأة العربية

القيمة التشخيصية لفحص الرنين المغناطيسي لقياس تدفق السائل الدماغي بالمخ

في تشخيص حالات الاستسقاء الدماغي ذو الضغط الطبيعي

المقدمة: يعتبر الاستسقاء الدماغي ذو الضغط الطبيعي مرضا نادرا، تحسن هذه الحالات بعد الجراحة لتركيب الصمام الدماغي غير مضمون، وذلك لعدم وجود أدوات تشخيصية دامغة حتى الآن تنبأ بانتظام الدماغي لهذه الحالات. الهدف: تقييم دور فحص الرنين المغناطيسي لقياس تدفق السائل الدماغي كأحد الوسائل الحديثة في تشخيص هذه المرض. أساليب البحث: تم أجراء 8 حالات تعاني من الاستسقاء الدماغي ذو الضغط الطبيعي في الفترة ما بين 2009 - 2011. تم تشخيص هذه الحالات إكلينيكيا، ثم تم إجراء فحص الرنين المغناطيسي لقياس تدفق السائل الدماغي لهذه الحالات. بعد ذلك تم إجراء بئل نخاعي قطني تشخيصي، وفي الحالات التي أظهرت تحسن إكلينيكيا بعد البئل، تم تركيب صمام نخاعي برموج الضغط. تم تحليل النتائج الجراحية. نتائج البحث: أظهرت النتائج حدوث نقص متفاوتة في كل الحالات. ٨٢% نسبة التحسن في الإدراك والمشي، و٥٠% نسبة التحسن في التحكم في البول. تم رصد علاقة بين مقدار التحسن الإكلينيكي وقياس كمية السائل الدماغي بالضيوفة الانتقائية. الاستنتاج: أثبت فحص الرنين المغناطيسي لقياس تدفق السائل الدماغي أنه وسيلة تشخيصية فعالة وأمنة يمكن الاعتماد عليها بصورة أكبر بدلًا من البئل التشخيصي في المستقبل، ويوصى بعمل دراسات تكميلية.